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RESEARCH ARTICLE

Large-scale environmental degradation results in inequitable impacts to already impoverished communities: A case study from the floating villages of Cambodia

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Abstract Cambodian subsistence communities within the Tonle Sap Great Lake area rely on resource extraction from the lake to meet livelihood needs. These fishing communities—many of which consist of dwellings floating on the lake—face potentially profound livelihood challenges because of climate change and changing hydrology due to dam construction for hydroelectricity within the Mekong Basin. We conducted interviews across five village communities, with local subsistence fisher people in the Tonle Sap in 2015, and used thematic analysis methods to reveal a fishery system that is undergoing rapid ecological decline, with local fishing communities increasingly experiencing reductions in available fish stocks. As a result, over 100 000 people living in these communities are experiencing a direct loss of well-being and livelihood. We discuss these losses and consider their implications for the future viability of Cambodian floating village communities.

Keywords Climate change · Distributive justice · Human well-being · Mekong basin · Subsistence livelihoods · Tonle Sap Great Lake

INTRODUCTION

Globally, significant changes to ecosystems and the services they provide to people are occurring. The diffuse effects of climate change are altering entire natural systems such as hydrological regimes, which is compounded by the impacts of land use change and development. A range of diverse and complex factors drives these changes, including economic growth in the developed world (Leal Filho et al. 2017), to gazettement of protected areas for nature conservation (Watson et al. 2014), and natural resource development for poverty alleviation in the developing world (Manorom et al. 2017).

Common to these drivers of major global change are distributive justice implications. Viewed from an environmental distributive justice perspective, such changes commonly produce inequitable outcomes for the world's poorest people, particularly in least developed countries. Rarely are the distributions of well-being benefits derived from ecosystem degradation proportionate to the resultant burdens that the poorest people are forced to bear (Pauline Dube and Sivakumar 2015). Furthermore, there is strong evidence which suggests that by contributing to human well-being, ecosystem services (that is those natural, biophysical processes people use to support their well-being) can reduce poverty (MEA 2005), as examined by Fisher et al. (2014) in their framework for analysing ecosystem services and poverty alleviation (ESPA). As such, not only are benefits and burdens resulting from ecosystem exploitation inequitably distributed to poor communities, their degradation also commonly results in a double inequity by reinforcing local poverty (Berbés-Blázquez et al. 2016).

While the environmental justice literature has a distinct focus on the justice implications of global climate change, there are far fewer studies examining the impacts of large-scale environmental changes on small, subsistence communities. Here we aim to partially address this gap by examining the state of environmental distributive justice within the Tonle Sap Great Lake (hereafter 'Tonle Sap'). To do so, we use Rawls' (Rawls 1971, pp. 5–6) second principle of distributive justice (Rawls 1971, pp. 5–6),

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applied through an environmental justice lens, that is: Social and economic inequalities, resulting from the degradation of natural resources, are to the greatest benefit of the least advantaged members of society.

Located in Cambodia, the Tonle Sap is a prime example of a highly productive, valuable and vulnerable wetland. Globally, wetlands are a key ecosystem type that provide many essential ecosystem services, such as supporting and regulating biodiversity habitat, provisioning food and other material goods, and cultural services (UNESCO 1994). Wetlands such as the Tonle Sap are generally highly productive, and are among the most valuable ecosystems on the planet (Al-Obaid et al. 2017). Due to being highly productive, wetlands around the world commonly support the well-being of large groups of people via ecosystem services, and as such, the well-being of these people are reliant on a healthy ecosystem (Fisher et al. 2014). However, wetlands are also characterised by their high level of vulnerability to systemic changes.

The Tonle Sap is located in rural Cambodia, where people often live subsistence lifestyles, meaning they are highly dependent on the direct provisioning of ecosystem services to meet their livelihood needs (Keskinen 2006). Over one million Cambodians directly depend on the Tonle Sap system, where they fish and farm food resources for day to day consumption and livelihood generation (Sokhem and Sunada 2006; FAO 2017). The lake is particularly critical for the livelihoods of over 100 000 people who live in 'floating villages'; communities which consist of dwellings that permanently float on the water of the Tonle Sap [Fig. 1; (Keskinen 2006)]. The livelihoods of people living within these communities are based predominantly on fishing activities (Keskinen 2006). As such, fish extracted from the lake are the main source of protein and livelihood generation for residents (CDRI 2013; Ratner et al. 2017). Given this dependence on the lake's natural resources, floating village communities are particularly vulnerable to any environmental changes that affect the fishery.

Unfortunately for these communities, environmental change in the Tonle Sap has been rapidly increasing over recent decades. Some of these changes are driven by the activities of the large human population living within the system (Keskinen 2006), and the high sensitivity of fresh wetlands to disturbances (Middleton and Souter 2016). However, the most significant environmental pressures are large scale and external to the system. Specifically, climate change and the modification of the Mekong River are the most substantial drivers of declines in the health of the lake's natural systems (Arias et al. 2012, 2014). While the activities which generate these pressures (such as manufacturing and damming) are undertaken to produce economic growth and enhance social well-being for some, it is likely that the environmental declines they also generate result in inequitable outcomes for floating villages. While these communities feel the effects of environmental changes most directly and profoundly, they receive few benefits from the development driving such change. As such, our present research examines the environmental distributive justice implications of major environmental changes on people living in the floating villages of the Tonle Sap. We aim to contribute to an understanding of how environmental inequity may affect subsistence communities.

Fig. 1 Prek Toal, is one of many floating villages located within the Tonle Sap. Most float on the water using barrels, or bundles of bamboo attached beneath the dwellings

The biophysical dimensions of the Tonle Sap Great Lake

In order to understand the livelihoods of people living within the Tonle Sap Great Lake, it is important to understand its unique and complex biophysical dimensions. The Tonle Sap is the largest lake in South East Asia and is part of a complex hydrological system that includes the Tonle river and the Mekong River which is the lake's primary tributary (Kummu and Sarkkula 2008). The most distinguishing feature of the lake is its exceptional annual flood cycle. Each year, the Tonle Sap floods and expands from ~ 2500 to 3000 km^2 in area and an average ~ 1.5 m in depth, up to ~ 10 000–16 000 km^2 in area and an average ~ 10 m in depth (Fig. 2). This flood occurs each year, between July and October, and is driven by the South East Asian monsoonal regime. During this period the monsoon generates over 60% of the Mekong Basin's total annual rainfall (Arias et al. 2014). The rains drive a vast flow of water into the Mekong river, which in turn reverses the flow of the Tonle river. During the flooding large amounts of nutrients are pumped into the lake, which is the foundation of its highly diverse set of freshwater ecosystems and fish species (FAO 2001; Kummu et al. 2008b; FAO 2017; Ratner et al. 2017). As such, the lake is characterised by its fisheries, which are among the most productive in the world (Keskinen 2006). The most recent estimates of total annual catch are between 180 000 and 250 000 tonnes (Chea et al. 2016). Catch from the Tonle Sap contributes around 50 percent of Cambodia's total catch, and around 16 percent of the national GDP (van Zalinge et al. 2000). Therefore the annual flood pulse is critical for the health of the livelihoods of people living within it (Keskinen 2006), and for the lake's natural areas (Arias et al. 2014).

The Tonle Sap's fisheries are dependent on a sustainable ecological system (van Zalinge et al. 2000). As such, the livelihoods of villagers living within the Tonle Sap are completely reliant on the fitness of the entire system's functionality, particularly its regular hydrological flood pulse system (Arias et al. 2014). Furthermore, much of the lake's biodiversity have life cycles that are synchronised to the flood pulse (Arias et al. 2014). Within these different ecosystems that range from floodplains to seasonally flooded grasslands, shrublands, and gallery forests (Middleton and Souter 2016), hundreds of fish, plant, bird,

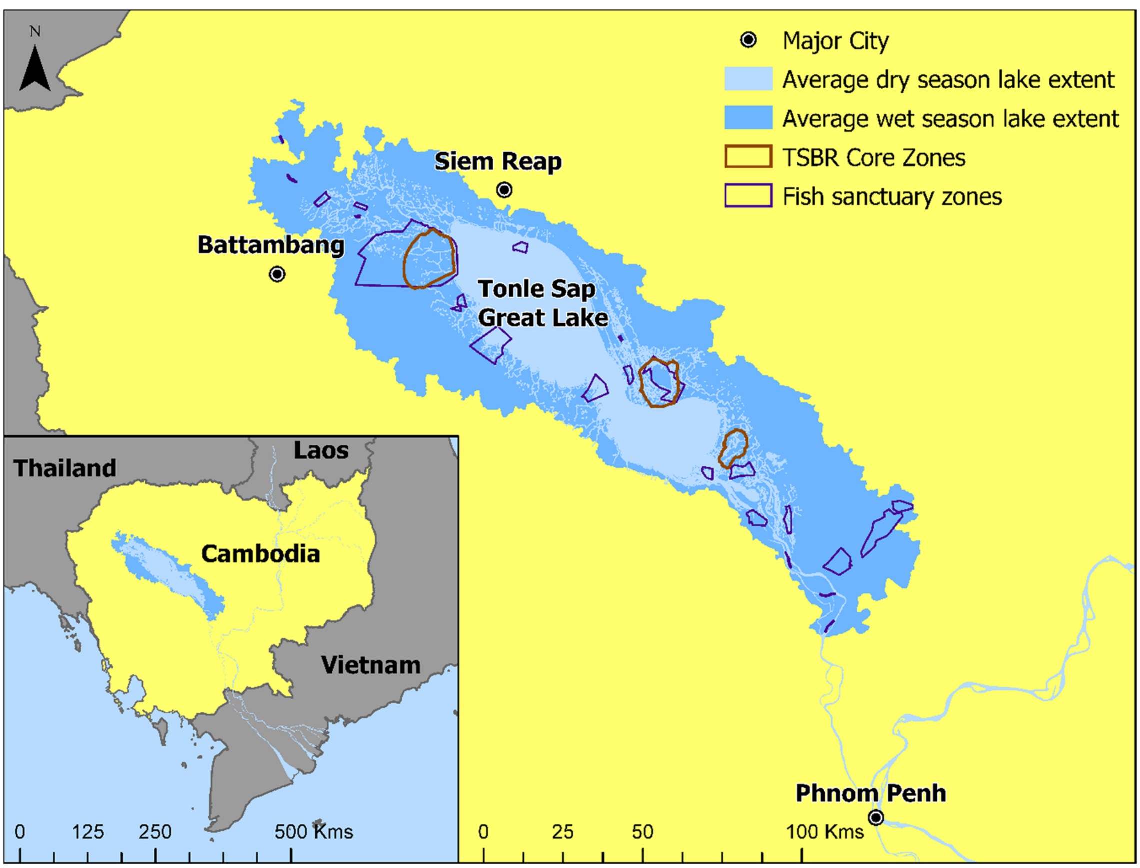

Fig. 2 The location and seasonal extents of the Tonle Sap Great Lake, tributaries, and key conservation areas. Map created using ESRI ArcGIS Pro with data provided by Wildlife Conservation Society, Cambodia (ESRI ArcGIS Pro 2017)

reptile, invertebrate, and mammal species occur, many of which have high nutritional or conservation value (Campbell et al. 2006; Roos et al. 2007; Arias et al. 2014). For a significant majority of Tonle Sap species the seasonally flooded ecosystems function as key habitat, which makes them critical for the ecological health of the lake (Arias et al. 2012).

Environmental protection within the Tonle Sap

In addition to the complex biophysical dimensions of the Tonle Sap, and due to its important social and ecological values the lake is also host to a diverse and intricate network of protected areas (Fig. 2). Understanding these protected areas is important as the lake's floating village communities often occur within and around them. Among the largest protected areas is the Tonle Sap Biosphere Reserve. Designated in 2001 by the United Nations Educational, Scientific and Cultural Organization (UNESCO) the Tonle Sap Biosphere Reserve officially recognises the lake's ecological significance (UNESCO 2007). The biosphere reserve aims to promote the conservation and sustainable use of the Tonle Sap's natural resources, with a particular focus on the lake's flooded ecosystems (UNESCO 2015). It hosts three of the lake's most ecologically diverse areas, which UNESCO designated as 'core zones': Prek Toal, Boeng Tonle Chhmar, and Stoeng Sen (UNESCO 2007). Core zones act as 'strict protected areas' where any exploitation of natural resources is prohibited under Cambodian law. Surrounding the core zones are buffer and transition zones, which allow increasing degrees of human activity. The transition zones are of particular importance to many floating village communities as this is where people are permitted to engage in economic activities, such as fishing. Overlapping the core zones at Prek Toal, and Boeng Chhmar are two Ramsar designated sites (Ramsar 2017). Ramsar designation highlights these sites as wetlands of international ecological significance, but confers no legal protection. In addition to the globally recognised conservation sites are a network of over 400 locally managed freshwater community fisheries and fish sanctuaries (Sok et al. 2012). Finally, there are three concentric ecological zones around the lake: the terrestrial zone where development activities are permitted; the floodplain zone where only specified development activities are permitted, and; the aquatic zone where habitat is strictly protected (Mak 2015). Adding to the complexity of the protected areas is the overlapping jurisdictional and governance structures of the Cambodian authorities responsible for their management. For example, the biosphere reserve and Ramsar sites are managed by the Ministry of Environment, whereas the Fisheries Administration of the Ministry of Agriculture, Forestry and Fisheries is responsible for the management of the community fisheries and fish sanctuaries. Furthermore, the Tonle Sap Authority is responsible for ensuring coordinated natural resource management across the entire Tonle Sap within the three ecological zones. All together the various protected areas and management authorities operating within the Tonle Sap make understanding its management and protection challenging for local people (Gillespie 2016).

Threats to the ecosystem and fishery

Regardless of the many layers of environmental protection within the Tonle Sap, it is still a system under significant threat. Since the 1980s the Tonle Sap has undergone significant environmental change due to clearing of vegetation, declines in water quality, and increased extraction of resources from people (Cooperman et al. 2012; Arias et al. 2014; Ratner et al. 2017). Furthermore, the lake is affected by major ongoing changes to its hydrology, flow regime, and flood pulse, which are due to rapid development of the upper reaches of the Mekong River (Lamberts 2008; Arias et al. 2012; Ziv et al. 2012).

Countries in the upper region of the Mekong River are increasingly constructing hydropower dams and reservoirs (Arias et al. 2012). For instance, there are more than 40 mainstream and tributary dams, irrigation, and water supply projects planned for implementation across Lao PDR, Thailand, China, Vietnam, and Cambodia in the next 20 years (Mekong River Commission 2016). The Mekong infrastructure projects put stress on the entire socio-ecological Mekong system, and in particular the Tonle Sap (Lauri et al. 2012). Of specific concern for the health of the Tonle Sap is the alteration of flow regimes (Arias et al. 2014). Damming of the Mekong dampens the annual flood pulse, which is vital for the health of the lake's ecosystems (Arias et al. 2012). Predictive modelling forecasts that dampening the flood pulse will create a twofold effect: in the dry season the average water levels will undergo a permanent increase, while in the wet season average levels will be permanently decreased (Piman et al. 2013). This will result in the average, permanently flooded area increasing between 17 and 40% (Keskinen et al. 2011). This is a serious issue as previous research suggests that even small changes in seasonal water extent are likely to compromise the lake's productivity (Baron et al. 2002; Arias et al. 2012, 2014). This is largely a result of the increase in permanently flooded areas dramatically reducing seasonally flooded habitats, which are the most significant for species of high economic and conservation values (Kummu et al. 2008a; Cunningham et al. 2011; Middleton and Souter 2016). Reductions in flooded habitats are likely to be rapid, as wetlands, in general, degrade much faster than other ecosystems (MEA 2000).

While modification of the Mekong is expected to be the primary driver of the Tonle Sap's declining health, climate change is also predicted to affect the system (Middleton and Souter, 2016; Arias et al. 2014). Within the Tonle Sap, climate change is increasing both atmospheric and water temperatures, the frequency of extreme weather events, and the variability of rainfall (Nuorteva et al. 2010). In fresh water systems, climate change modifies hydrological patterns such as precipitation, evaporation, and flooding, (Erwin 2009; Lemieux et al. 2014). These modifications result in a scarcity of fresh water, and hydrological systems become strained.

Previous research has modelled many scenarios for both the effects that alteration of the Mekong system and climate change will have on the Tonle Sap ecosystems (Kummu and Sarkkula 2008; Lamberts 2008; Keskinen et al. 2011; Arias et al. 2012, 2014). Although there is a degree of variability between studies, all agree that large tracts of the lake's seasonally flooded habitats will be lost. This will result in widespread reduction in the lake's productivity (Lamberts 2008). For floating village communities, reductions in the lake's productivity is a serious cause for concern. A decrease in the productivity of the lake will result in a decline in the fisheries, which is the only source of livelihood generation for most households (van Zalinge et al., 2000; CDRI 2013). While there is a body of research highlighting how ongoing anthropogenic change will adversely affect the natural systems of the Tonle Sap (Kummu et al. 2008b; Kummu and Sarkkula 2008; Orr et al. 2012; Arias et al. 2012, 2013, 2014), comparatively little research has been conducted to understand how these changes will affect the lives of the communities living within the lake's floating villages. As such, our research question is: *How are the fishing people of the Tonle Sap floating villages experiencing major environmental changes?* To achieve this we interviewed people in five Tonle Sap floating village communities using thematic analysis methods to record: (1) people's experiences living in this complex natural system; (2) how they perceive ongoing environmental changes in the system, and; (3) if and how they respond to these changes. By collecting and analysing these experiences and perceptions our aim was to understand the observations of, and responses by, communities to ongoing changes in the lake's ecosystems.

MATERIALS AND METHODS

Prek Toal biosphere reserve and surrounding communities

We undertook an interview-based study in a selection of communities to understand and record the experiences and perceptions of people living in floating villages within the Tonle Sap. We elected to visit the five communities surrounding the Prek Toal Core Area of the Tonle Sap Biosphere Reserve (Fig. 3), as these communities were recommended to us by Cambodia-based conservation practitioners as representative of the demographic makeup and livelihood model of the Tonle Sap (fishing people), and due their proximity to other areas of interest. These villages (Thvang, Kampong Prahok, Anlong Ta Uor, Prek Toal, and Kbal Taol—henceforth Prek Toal communities) are subsistence communities permanently floating within the Tonle Sap floodplain, and are adjacent to several protected area and fishery management zones, and as such, are of interest in understanding how environmental change affects people in the Tonle Sap. The Prek Toal communities are adjacent to various Community Fisheries on one side, and to the former Fishing Lot No. 2, now a Fish Sanctuary (no-take zone) that overlaps and surrounds the Prek Toal Core Area of the Tonle Sap Biosphere Reserve (itself also the Prek Toal Ramsar site) within which there is a Community Protected Area. Over 10 000 people make up these communities, and by international standards many are living below the poverty line (Varis et al. 2006). This makes the Prek Toal communities highly vulnerable to changes to the resources that provide for their livelihoods. The five communities represent a relevant sample for understanding the complex trade-offs and interactions between livelihoods, nature, resource management, and conservation in the Tonle Sap.

Data collection

We conducted semi-structured interviews with subsistence fisher people ($n = 19$) using qualitative interview methods (Guest et al. 2006). Before any recorded interviews took place, we met with the chief of each of the villages, and the commune chief. Village chiefs are responsible for governance and community leadership within their village. Communes are a multi-village Cambodian administrative division. The commune chief we spoke to governs the Kaoh Chiveang commune, which includes all five villages. There were several purposes for these meetings. First, we explained the nature of our research, and importantly, asked for their permission and endorsement to conduct research within their communities. Once permission was granted we asked the chiefs to assist us in understanding the communities, and the issues people face, relevant to our research. As such, the village chief interviews were vital for participant recruitment, and to design our interview questions and interview guide (Supplementary material S1).

With the assistance of the chiefs we were able to use purposive sampling, targeting those people with fishing as

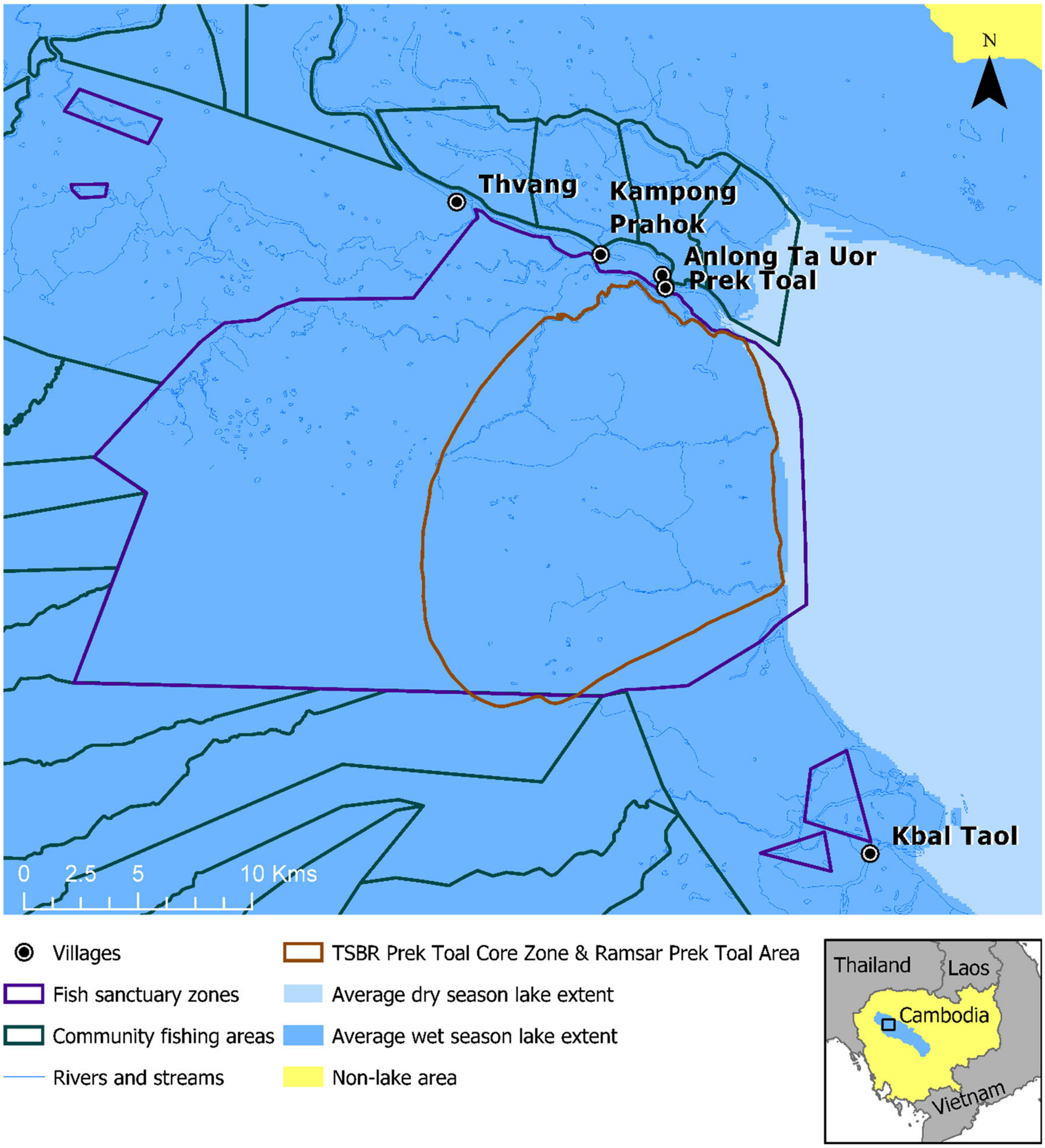

Fig. 3 Map of floating villages, and other features surrounding the Prek Toal Biosphere Reserve. Note that the background blue area in the main map indicates that the entire area is flooded in the wet season. Map created using ESRI ArcGIS Pro with data provided by Wildlife Conservation Society, Cambodia (ESRI ArcGIS Pro 2017)

their primary means of livelihood generation, who had long-term residence within the community. This was decided as fishing is by far the most common and important livelihood activity in the communities, and long-term residence would avoid some of the bias that occurs with shifting baselines (Sáenz-Arroyo et al. 2005). Further participants were engaged using snowball sampling (Lewis-Beck et al. 2004), by asking participants for recommendations following interviews. Participant sample size ($n = 19$) was established based on data saturation techniques (Guest et al. 2006; Francis et al. 2010; Bryman 2012; Bernard and Gravlee 2014). We then conducted interviews with all participants in their villages using participatory tools including seasonal fishing charts (see Supplementary material S2), and participant-generated maps of the local area and features (see Supplementary material S3). The creation and discussion of these charts were critical as discussion tools during the interviews, however the sample size is too small for any quantitative analyses. As some of the issues discussed in our interviews were potentially contentious within the community or could place participants at risk, we collected no identifiable information from participants. All discussions with chiefs and interviews with participants were subject to ethics approval, granted by the University of Queensland (number 20150701). We conducted all interviews in the Cambodian language, Khmer, with the assistance of a translator. All interviews were recorded for later translation and transcription. It is important to note that as interviews were translated, some meaning from either interviewer or participants may have been unclear. In order to reduce this issue, we ensured interview prompts and probing questions were simple and easy to communicate.

Data analysis

The lead author undertook all analyses, including designing the strategy, developing the code book, coding the data, and performing the thematic analyses. A data corpus was created which consisted of (1) the transcribed interviews, and participant-generated (2) fishing charts, and (3) participant-generated maps. Professional Cambodian translators were contracted to translate and transcribe audio data from Khmer into English. The field translator conducted translations of fish charts and maps. Data were not quantified due to the small sample size suited to qualitative analysis, and the semi-open-ended structure of the interviews. The purpose of the thematic analysis was to explore participant responses, in the context of our research aims. The interview data largely informed the analytical strategy, we used inductive analysis to derive thematic codes from participant responses.

Thematic identification for creation of our code book was used (see Supplementary material S4). Codes were developed using the literature, and key words, trends, themes, and the interview data itself (as per Guest et al. 2012). Throughout the screening processes only data considered relevant to the research aims were analysed. All data coding was undertaken using R v. 3.3.3 (R Core Development Team 2015), with qualitative data analysis package RQDA v. 0.2-8 (Huang 2014).

Coding required three data screening phases (as per Frith and Gleeson 2004):

1. An initial screening of data for the purposes of identifying themes and sub-themes, and organisation of themes into a draft code book.
2. A second screening of data to test the precision of, and to refine, the code book.
3. A final screening of data, where we re-coded all data using the final, refined code book.

Thematic analysis methods were used to identify, analyse, and describe thematic patterns within the coded datasets (Guest et al. 2006). As the aim was to capture community perceptions and experiences, we determined thematic prevalence based on the number of interviewees who discussed any particular topic. Data were analysed and described using a narrative approach (Kitzinger and Willmott 2002; Braun and Clarke 2006), whereby we extracted an understanding of participants' realities from the data.

RESULTS

Our analysis revealed several key themes from the data: (1) fishing is increasingly critical to local livelihoods, (2) people believe that the fishery is highly vulnerable to environmental change, and (3) people believe the fishery is undergoing rapid declines.

Fishing is critical to local livelihoods

All participants explained that the majority of floating village families catch fish as their primary source of food and income. Some villagers sometimes buy fish, but most villagers generally catch fish to meet their needs. For those who buy fish, buying is mainly restricted to the dry season, when the catch is reduced.

There was little relevance of the fish species caught. Participants described how families will both eat and sell any fish species that they catch. However, they tend to only eat the smaller fish, which have less market value, whereas larger fish are sold. Some participants described how the majority of the income derived from selling fish is spent on basic food, and in particular rice which is eaten at each meal, year-round. Participants explained that the fishery changes from month to month, and that different fish species occur at different times of the year, with the dry season being lengthened and increasingly hot. As different species have different monetary values, this has the effect of making family incomes seasonal.

Participants also discussed the local practice of aquaculture (fish and, very rarely, crocodile farming). They explained that aquaculture is usually restricted to those in the community who are relatively wealthy. This is due to the capital required to set up the fish farms, which require timber and other resources which are scarce in the area. However, many participants also explained that eel farming is a very common practice, as it does not need any capital. To raise caught eel people simply use the hollows of bamboo stalks, submerged in water. The majority of fish produced in the farms is sold to traders, with few farmed fish being eaten by farm owners. Many participants explained that fish farmers will still catch some fish for consumption, but also for use as feed in the farms. The majority of fish farmed in the region are Snakehead species (*Channidae)*, meaning this farming is technically illegal.

However, participants spoke of how these species are of the highest value for resale and as such, very desirable. There was no mention or evidence that these restrictions are in any way enforced.

People believe the fishery is highly vulnerable to environmental change

When people where asked about when and where they go to fish, participants talked about how villagers fish in all open aquatic and flooded habitats (grasslands, shrub lands and gallery forests) in the area. However, access to different areas is seasonal, and can be restricted by Cambodian authorities. Participants described differences in fishing between the wet and dry seasons. During the dry season, villagers fish within and along the shore of the Tonle Sap, within and along the shore of local streams and channels, and along the border of the protected areas. In the wet season, people will fish anywhere that the water has risen. However, communities reduce fishing efforts in the deepest areas of the lake during the wet season due to the danger of large waves and storms. While most people told us that they can never fish in the protected areas in either season, some stated that "a little poaching" occurs within the protected areas as enforcement is either lax or prone to minor corruption.

We also spoke with participants about when and where fish are the most abundant, and where the greatest catch volume occurs. Participants explained that the greatest catch occurs during the transition between the end of the dry season and the beginning of the wet season, as the water levels rise. Participants told us that fish are most abundant in and around the nearby protected areas, and that the best catch occurs along the borders of the protected areas. Participants also told us that the catch is better along the shores of the lake and local streams than in other areas. When asked why they thought the protected areas have the most fish, people told us that it is due to government prohibitions, and because armed guards patrol these areas. Furthermore, they spoke of how these areas are most abundant as this is where fish migrate to during the dry season. Many participants told us that the protected areas are important for the local fish, however some participants said that they are dissatisfied with prohibitions and that they would prefer complete fishing access. We asked participants about the effects of extreme weather on the communities, including drought, very high floods, and storms. Participants explained how drought (such as in 2002 and 2015) has terrible effects on communities. The majority of people described that 2015 was the hottest and driest year in living memory, and how the water level increased slowly during the start of the wet season. They also explained how the lake water can become polluted and 'smell bad' during drought. Many people described how during a drought the fish catch is much smaller than the average year. They attributed this to many of the dry season fishing areas, such as local streams, completely drying up or becoming stagnant, which kills the fish. Furthermore, participants spoke of how high water temperature in local streams causes a high rate of fish mortality. Fish that die in this manner are rendered inedible. We asked participants about the effect that unusually high annual floods (such as in 2011 and 2013) have on families in the villages. All participants stated that during these floods the fish catch is greater, and many also told us that the size of fish is larger. A consistent comment from many participants was 'big flood, big fish'. Additionally, we asked participants about the effect of the severe storms which occur in the area. Most participants told us that storms are not very disruptive, but can result in a short-term suspension of fishing activities, and damage fishing gear.

People believe the fishery is undergoing rapid declines

The participants spoke of perceptions about changes to the fishery in recent history (the last 10–20 years). There was a very strong consensus that the fishery has rapidly declined, both in terms of catch size and individual fish size. Participants explained how every fish species they catch has declined in abundance by anywhere between 30 and 90%, and that some species had disappeared altogether. Many participants showed us that the size of some species had gone from the girth of their forearm down to the girth of a few fingers. When prompted about why they thought that the fishery had declined, participants gave a range of reasons although virtually all participants told us that the main causes for declines in the fishery were due to an (unspecified) increase in the local human population, resulting in overfishing, and that many villagers were now using modern fishing gear, such as electric nets. Other less common reasons given for the declines were the increasing hot weather, water pollution, and illegal fishing in restricted areas.

We prompted the villagers to discuss how they respond to the declines in the fishery, and how they adapt to extreme weather such as drought and flood. Most people told us that the communities do not respond or adapt at all. Due to the much-reduced catch, many families now need to supplement their catch by buying fish to eat from local traders. However, often families cannot afford to buy fish. A few participants reported that during drought they can go through periods where "people almost have nothing to eat" as they have no alternate source of food or income. We were told that during extreme conditions such as drought, even though people know there is little catch, most will still try to undertake fishing activities. Few fisher people will change to alternative livelihood activities. This was attributed to villagers not having any choice for alternative livelihood generation in the floating villages. Some participants explained that families who can afford the expense of buying food will leave the village for factory work in Thailand.

DISCUSSION

The ongoing and projected changes in the Tonle Sap's ecosystems are expected to increasingly compromise the lake's ecosystems (Arias et al. 2014). As such, it is very likely that the Tonle Sap fisheries will become increasingly less productive. As a result, floating village communities will suffer from significantly reduced livelihoods. This outcome clearly fails the requirements of environmental distributive justice as the well-being outcomes of the developments driving these changes are not equitably distributed to those most in need. Rather, our findings demonstrate that floating village communities are the most likely people to suffer from ecosystem service declines in the Tonle Sap. We demonstrate that people believe there are rapid changes and declines in the ecological system. Furthermore, we show how floating villagers believe that the entire fishery has declined rapidly over the past two decades, a phenomenon which is likely true given the consistent reports in interviews, and supporting empirical studies (Arias et al. 2014; Ratner et al. 2017). Interestingly, our results show how the effects of climate change and hydrological alteration, such as reductions in seasonally flooded habitats (Arias et al. 2012), are to some extent invisible to floating villagers. Rather, they largely attribute fishery declines to overpopulation and the increased use of illegal fishing gear.

Importantly, our research also demonstrates how people living in floating villages have very little capacity, opportunity or means to adapt to these events and changes in situ. While some families can seek international factory work, or trade fish, the majority of people describe themselves as too poor to afford the capital required for such activities. We also found that in many cases, people may not attempt to adapt at all, rather they simply continue fishing in much declined waters. This finding is similar to previous survey based research in Cambodia, where over 40% of participants stated they responded to severe drought by either organising religious ceremonies, or planting crops as usual (MoE 2005). This lack of adaptive capacity in floating villages is very likely due to economic poverty (Keskinen 2006). Poverty has been shown in general to make societies highly vulnerable to changes in livelihoods (Shepherd and Brunt 2013). For floating village communities, a distinct lack of alternative livelihood options further exacerbates this vulnerability. The vulnerability of floating villages is a serious concern as communities with little capacity to adapt to threats can fall into poverty traps, which if left unresolved can cause catastrophic social breakdown (Carpenter and Brock 2008). As such, if the Tonle Sap's ecosystems continue to degrade alongside the conditions of poverty suffered by floating villagers, it is unclear if and how these communities will be able to survive into the future.

While the overall adaptive capacity of floating villages is low, the protected areas near these villages may play a role in buffering their vulnerability to change. While the role of the protected areas in conserving biodiversity is obvious, the co-benefits to communities can be less so (Adams et al. 2004). By maintaining healthy habitat the protected areas also provide important ecosystem services to nearby communities (Middleton and Souter 2016). In the Tonle Sap, protected areas offer sanctuary, and spawning grounds for the fish on which the communities depend. Furthermore, participants described an effect very similar to the fishery spill over seen around marine protected areas (Russ and Alcala 2011). In well managed marine reserves, species thrive in the absence of human pressure and as a result, fish can 'spill over' into the surrounding waters (Goñi et al. 2010). However, the extent of such an effect in the Tonle Sap is poorly understood and should be the subject of future research in this region. Regardless of the potential spill over, previous research (and one participant who we interviewed) describe the protected areas as a burden on communities (Gillespie 2016). For local people, the complex nature of the overlapping layers of protection and regulation for the environment can be confusing. Gillespie (2016) reported that while many local people value the services protected areas provide, their management was described as 'clunky' and 'confusing'. This confusion is a concern, as local communities are those most affected (positively or negatively) by the protected areas. This is also of concern from a biodiversity conservation perspective, as a lack of buy-in from local communities have been shown to potentially undermine the effectiveness of protected areas (Beger et al. 2004). As such, there is a need for an improved understanding and communication of human and biodiversity conservation relationships in the Tonle Sap. This presents an important research need which may identify opportunities for attaining benefits for both people and nature in Cambodia.

Future studies assessing protected area spill over, or the human–nature relationships in the Tonle Sap would benefit from improved data collection methods. In our study, the use of translation from Khmer to English to conduct interviews is a time-consuming and exhausting task which introduced the potential for issues of miscommunication and misunderstanding. We therefore recommend that native Khmer speakers undertake future interview-based research with floating village communities.

While the communities and the biophysical nature of the Tonle Sap are highly unique, the lack of distributive justice is not. Globally, these wetland ecosystems provide the majority of resources required by local people to support their livelihoods and well-being. However, many (if not all) major wetland systems are in a state of decline due to large-scale anthropogenic changes, which result in the unfair distribution of burdens to local communities. Recent examples include subsistence or poor communities impacted by the Belo Monte dam in the Amazon Basin (Abers et al. 2017), and the Grand Ethiopian Renaissance Dam on the Blue Nile River (Nalepa et al. 2017). Even within the Mekong the situation in the Tonle Sap is not unique, with agrarian communities throughout the Mekong suffering similar injustices (Tilt and Gerkey 2016). As such, understanding and addressing issues of distributive justice in wetland ecosystems is a problem of global concern. The drivers of large-scale environmental change in the world's wetlands are happening at (regional and global) scales which are beyond the ability of local communities to affect. As such, the environmental degradation of wetlands is also an issue of social equity and distributive justice. The people, businesses, and nations who are receiving the benefits from degrading these systems (i.e. gross domestic product growth from producing greenhouse gas emissions, or the sale of hydropower) are forcing others, such as the Tonle Sap floating village communities, to bear the costs.

However, there are efforts being made to address these inequities. The Mekong River Commission (the intergovernmental organisation which manages the development of the Mekong River) state they will make up for the losses and spread the benefits expected from hydropower development to small communities via benefit sharing mechanisms (MRCS 2014). Likewise, climate adaptation funds, such as the Adaptation Fund, the Green Climate Fund, and the Special Climate Change Fund aim to commit extensive resources to helping developing countries adapt to climate change. However, there is no clear indication if (or how) any such funds may or may not be distributed to specific communities (such as floating villages within the Tonle Sap). The Mekong River Commission documentation related to benefit sharing offer little to no detail regarding beneficiaries or actual distribution mechanisms, and this was reflected in our interviews with participants making no mention of any such arrangements. Similarly, the climate adaptation funds offer little detail on actual fund distribution mechanisms and are struggling to gain financial commitment from wealthy nations (Kumar 2015). As such, there is a critical need for clear and detailed mechanisms for benefit sharing to Tonle Sap communities. These mechanisms urgently need to be formed and implemented before livelihoods in the lake become further compromised. The parties driving environmental degradation in the Tonle Sap have a clear moral obligation to share the benefits of their activities with those bearing the costs. These issues also have implications at a broader scale as these issues are hardly unique to the Tonle Sap. Previous research shows that inequitable impacts of large-scale environmental degradation can be found the world over (Althor et al. 2016), and much like the case of the Tonle Sap, the main beneficiaries of environmental exploitation elsewhere pay relatively few costs (Ehrlich et al. 2012; O'Faircheallaigh 2015).

CONCLUSION

Globally, large-scale environmental changes threaten the viability of subsistence communities. Development along the Mekong basin will permanently change the ecological structure of the Tonle Sap. Global climate change will increase temperatures within the lake, and increase the incidence of extreme weather events. The development of dams on the Mekong River will affect the Tonle Sap's hydrology, leading to poor consequences for sustainability of the fishery. Furthermore, the effects of Mekong basin development and climate change on the Tonle Sap are likely to intensify each other. As a result, the lake's ecosystems will become increasingly stressed, and some habitats such as the lake's seasonally flooded habitats will potentially disappear altogether. Permanent loss of habitat in the Tonle Sap could lead to a collapse of the lake's (already) stressed fisheries. If the lake's fisheries fail, life in floating villages will become even more difficult, if not impossible. As such, climate change and the development of the Mekong basin will dramatically, and potentially catastrophically, affect these people. Furthermore, given the low adaptive capacity of these communities, it is unclear how they might respond or adapt to a loss of their main livelihood source. Efforts to secure a sustainable future are needed to correct the inequities of the manifold pressures—climate change, Mekong basin development, fishery decline, population growth—affecting the people of the Cambodian Tonle Sap Great Lake.

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